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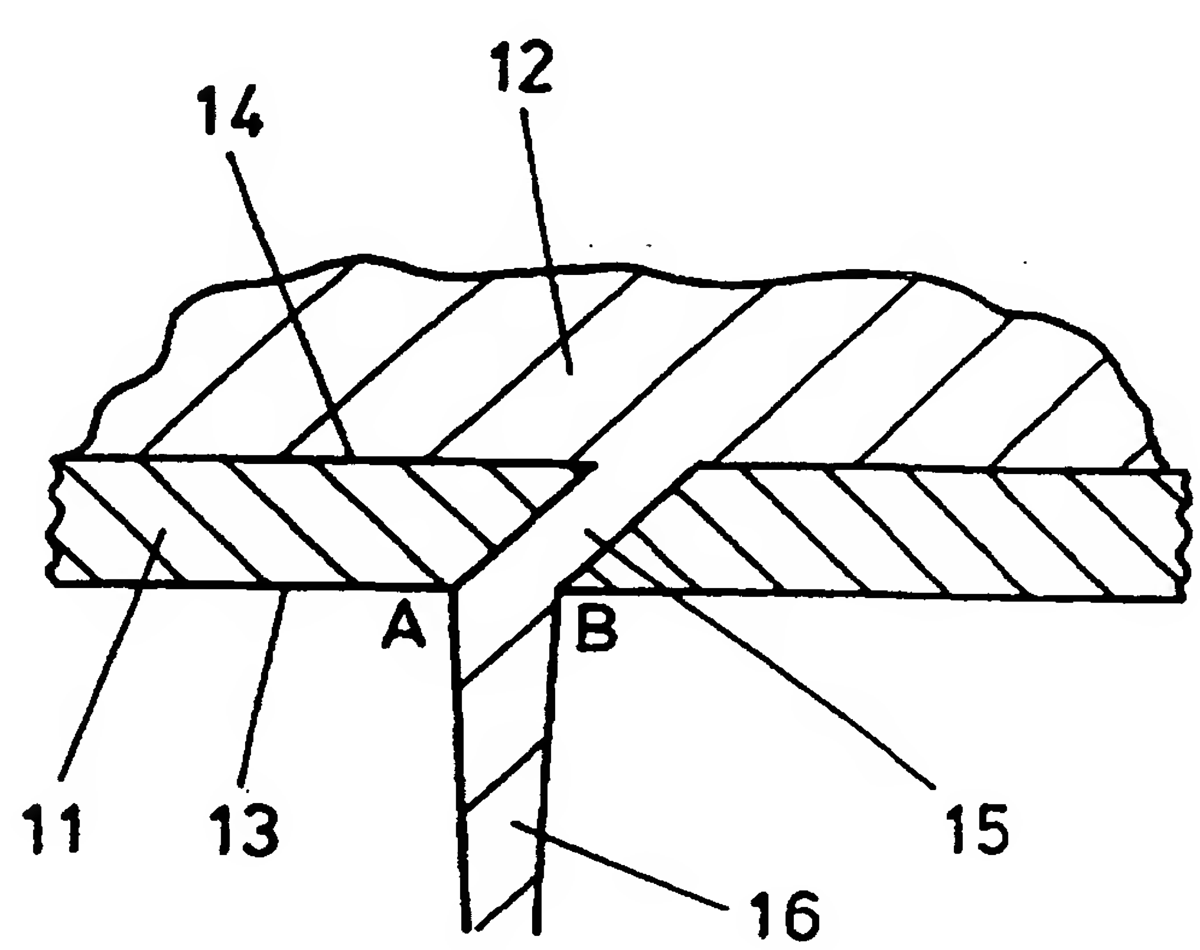

(57) Abstract

A method for producing a substantial helical or zig-zag crimp in a continuous filament (16) is described. The method comprises the steps of generating a turbulence in a thermoplastic material (12) intended to form the filament (16) whilst the thermoplastics material (12) is in its glass transition phase, and maintaining stresses induced in the formed filament (16) by said turbulence while the filament material passes into its crystallised phase.

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METHOD AND APPARATUS FOR PRODUCING CRIMPED THERMOPLASTICS FILAMENTS

This invention relates to the production of crimped filaments made from long chain molecule thermoplastics materials and relates particularly, but not exclusively to fibres made from polypropylene.

Filaments made from long chain molecule thermoplastics materials are well known in the art and are generally drawn through holes in a spinnerette plate from a body of the molten plastics material above the spinnerette plate. When produced in this manner, the filaments are essentially straight and without crimp. Whilst continuous straight filaments, without crimp, can be used for a number of commercial processes, a crimping of the filament is highly desirable for a number of commercial applications, in particular in the clothing or woven material industries.

One known method for applying a crimp to a continuous filament is to pass the filament, in heated conditions, between a pair of meshing gear wheels but the crimp obtained by the gear wheels is very limited and lies in only one plane of the filament. If the filament is rotated about its axis whilst passing through the gear wheels a helical crimp can be produced but said crimp will require the additional expense of providing a means of rotating each filament and the crimp is relatively weak.

In another known method for crimping filaments the filaments, whilst in heated condition, are cooled on one side and, as the filaments cool, differential stresses will be induced across the diameter of the filaments. When the drawing tension is released from such filaments a wavy, or helical, crimp will develop but, in practise, the degree of

crimp applied to and retained by such filaments is relatively small.

Preferred embodiments of the present invention seek to provide a method for making filaments wherein the filaments have a substantial, generally helical or zig-zag crimp therein.

According to the present invention there is provided a method for producing a substantial helical or zig-zag crimp in a continuous filament, the method comprising the steps of generating a turbulence in a thermoplastic material intended to form the filament whilst the thermoplastics material is in its glass transition phase and maintaining stresses induced in the formed filament by said turbulence whilst the filament material passes into its crystallised phase.

Viewed from another direction the present invention provides a method for inducing a substantial helical or zig-zag crimp in a continuous filament of a thermoplastics material comprising the steps of inducing turbulence in the polymer flow immediately prior to, or at the point of, formation of the filament.

Preferably the turbulence is concentrated towards one side of the cross-section of the filament.

In a preferred embodiment, the molten filaments are rapidly cooled to solidification so that the disturbance of the molecular structure is locked into the crystallised polymer.

During subsequent processing of the filaments when the axial tension is removed from the filaments, the stresses induced into the filaments before or leaving the spinnerette plate cause uneven tensions in the filaments to

be relieved which results in distortion of the filaments and produces a pronounced helical or zig-zag crimp effect in each filament.

In a preferred embodiment, the method further comprises the step of drawing the filaments through holes in a spinnerette plate wherein each hole makes an angle, preferably an angle of substantially 45°, to an external face of the spinnerette plate.

Alternatively, or in addition, the turbulence in the molten plastics may be generated by a change of the cross-sectional area of each hole through the spinnerette plate.

In a preferred embodiment the change of cross-sectional area of each hole through the spinnerette plate is in the form of a step.

In one embodiment the hole through the spinnerette plate from which the filament is drawn is of different cross-sectional areas, with the smallest cross-sectional area at that end of the hole from which the filament is drawn.

In a further embodiment each said filament has a non-circular cross-sectional area and preferably the filament has a cross-sectional shape which is generally equivalent to a full circular cross-section with substantially one quarter of the circle removed.

Preferably the non-circular cross-sectional area of each filament is induced by the cross-section of a hole in a spinnerette.

The present invention will now be described further by way of example only, and not in any limitative sense, with reference to the accompanying drawings in which:

Fig 1 shows, diagrammatically and in cross-section, one arrangement for spinning a filament in accordance with the invention;

Fig 2 shows, diagrammatically and in cross-section, a second arrangement for making a filament in accordance with the invention;

Fig 3 shows, diagrammatically and in cross-section, a third arrangement for making a filament in accordance with the invention;

Fig 4 shows, diagrammatically and in cross-section, a fourth arrangement for making a filament in accordance with the invention;

Fig 5 shows, diagrammatically and in cross-section, a fifth arrangement for making a filament in accordance with the invention; and

Fig 6 shows a cross-section through one form of filament in accordance with the invention.

In all the examples illustrated a spinnerette plate 11 supports the bottom of a body 12 of molten thermoplastics material thereon and the spinnerette plate 11 presents an external face 13, which is exposed to atmosphere and in the illustrated examples is arranged to be substantially horizontal, and an internal face 14 exposed to the body 12 and upon which the body 12 rests.

In the example illustrated in Fig 1 the spinnerette plate 11, has a hole 15 formed therethrough and in the example the hole 15 is inclined at an angle of 45 degrees to the external face 13 of the spinnerette plate 11.

A filament 16 of the thermoplastics material is drawn through the inclined hole 15 and is tensioned substantially at right angles to the plane of the surface 13 by the filament drawing arrangement (not shown).

Because the filament 16 is subjected to the rapid change of direction on leaving the hole 15, and due to the axial tension applied at an angle of 45 degrees to the axis of the filament formed in the hole 15, the filament 16 has differential stresses formed therein and which stresses cause the filament 16 to adopt a substantial degree of helical or zig-zag crimp when the filament 16 is allowed to relax.

In the example illustrated in Fig 2 a hole 17 through the spinnerette plate is substantially at right angles to the plane of the surface 13 but in this example the filament 18 is drawn off at an angle of some 45 degrees to the plane of the surface 13. By this means turbulence in the plastics material forming the filament 18, and the differential stresses in the filament 18 in being turned to the line of draw of the filament 18, generates differential stresses in the filament 18.

In the example illustrated in Fig 3 a filament drawing hole 19 in the spinnerette plate 11 is formed by two cylindrical holes formed in opposite faces of the spinnerette plate 11, with their axes substantially parallel but one axis offset from the other axis, and with the holes overlapping to form the hole 19 passing through the spinnerette plate. In this example the plastics material 12 flowing into the hole 19a and subsequently hole 19b is subjected to a great deal of turbulence, caused by the upwardly facing crescent shaped ledge 19c and the downwardly facing crescent shaped ledge 19d within the hole 19, and whilst the filament 20 is being formed.

In the example illustrated in Fig 4 a hole 21 through the spinnerette plate 11, and from which the filament 22 is drawn, is again formed in two parts, the part 21a in the surface 14 and the hole 21b, of smaller diameter which opens to the surface 13 of the spinnerette plate 11. In this example the hole 21b is fully exposed to the hole 21a but, being of smaller diameter, forms a crescent shaped ledge 21c between the holes 21b and 21a. Thus, in this embodiment, the thermoplastics material flowing to form the filament 22 is subjected to substantial turbulence as the filament 22 is formed.

In the example illustrated in Fig 5 there is disclosed one method by which the spinnerette plate 11 can be formed to have a filament drawing hole 23 formed by two holes of different diameter. Thus, in this embodiment, the spinnerette plate 11 is formed by two elements, 11a and 11b, a first hole 23a is formed in the element 11b, a second hole 23b is formed in the element 11a, the hole 23b has a smaller diameter than the hole 23a, and the elements 11a and 11b are so assembled that the hole 23b is fully opened to the hole 23a. The hole 23b, being of smaller diameter than hole 23a, allows the element 11a to present a crescent shaped ledge 23c in the flow path through the hole 23. The ledge 23c generates substantial turbulence in the flowable plastics material immediately before, and during, formation of the filament 24.

It will be appreciated by persons skilled in the art that the method of assembly of the spinnerette plate 11 illustrated in Fig 5 could be used in the embodiments of Figs 3 and 4.

It is believed that the turbulence generated in the flowable plastics material immediately prior to, and whilst the said material is being brought to a condition where the filament is being formed, generates substantial shear

across the width of the filament as the filament is formed and, when the axial tension of the drawing apparatus and subsequent processing apparatus is relieved the differential stresses across the width of the filament are at least partially relieved by the filament adopting a pronounced helical or zig-zag crimp.

However, to increase the crimp effect the filaments 16, 18, 20, 22 and 24 may be formed in respective holes, 15, 17, 19, 21 and 23 to have a non-circular cross-section and Fig 6 illustrates one cross-section, comprising a full-circular cross-section with one quarter of the circle removed, and when the filament is being drawn from the holes, 14, 17, 19, 21 and 23 the points A and B of the filament 25, illustrated in Fig 6, may be disposed close to the points A and B as illustrated in Fig 1. Further, the non-circular cross-section filaments 25, as illustrated in Fig 6, may be subjected to a rapid differential cooling, which will again increase the crimp formed in the filaments.

It has been noted that polymers with a lower Melt Flow Index exhibit a greater tendency to produce self-crimping filaments. Furthermore, it has been shown that the lower the extrusion temperature and hence the higher the viscosity of the molten polymer, the greater is the shear and the greater the effect of self-crimping will be.

Whilst it has been shown in practice that this system of self-crimping is not dependent on asymmetric cooling such cooling when combined with the method of the embodiments described above can produce an enhanced crimp in the filaments. It has been observed during trials that the degree of crimp is dependent on the temperature and time delay between the polymer with turbulent flow emerging from a spinnerette, to the time it solidifies and changes to the crystalline state.

When polypropylene changes from a molten state to the solid state, it does so in two stages. The polymer first of all passes through the "glass transition" stage. At this stage the polymer is amorphous. Stresses in the polymer in the glass transition state will self-anneal if maintained at the glass transition temperature, but at a much slower rate than in the molten state.

In the second stage, once the polymer has passed through the glass transition state, it begins to crystallise. When this occurs any molecular stresses in the polymer are locked into the crystalline structure. It is these irregular stresses which cause the fibres to distort i.e. self-crimp when they are drawn (orientated).

Further, whilst it has been observed by trials that the self-crimping effect by this method as described is not dependent simply on asymmetrical cooling the asymmetrical cooling is effective if it takes place at the correct point in the process. Thus a filament cooled by blowing air from more than one direction relative to the filament produces the same effect providing the filament solidifies to the crystalline state before the internal stresses are dissipated.

It has also been shown that the self-crimping effect can be achieved without the use of blowing air or gas onto the filaments. Contact with a cold surface i.e. a roller with a cold surface or non-rotating cylindrical cold surface or a flat cold surface produces the same effect providing always that the polymer is cooled to the crystalline state before the imparted stresses are dissipated.

The rate of cooling in a stream of gas (air) is not dependent on air temperature alone but also on the "wind chill" effect due to velocity. It is therefore possible to affect the degree of crimp in the final product by using

quench air at variable velocity with constant temperature, or vice-versa, providing always the filament is cooled to the crystalline state before the internal stresses have dissipated.

It has been found that a preferred method of cooling the filaments is by subjecting the molten filaments emerging from the spinnerette to a stream of "cold steam".

"Cold steam" can be produced by passing water into an ultra-sonic whistle energised by compressed air. The "cold steam" comprises minute particles of water which rapidly evaporate on contact with the filaments. The latent heat of vaporisation produces a very pronounced reduction in temperature.

This method of cooling is particularly advantageous because it only requires to have a flow of "cold steam" with minimal velocity so that the filaments are not vibrated or caused to flutter. This is a problem associated with using air at high velocity, and results in adjacent filaments touching and bonding together.

Understanding of the above embodiments will be further assisted by the following examples.

Example 1

A spinnerette plate was drilled with 3454 holes of cross-sectional shape as shown in Figure 6, each hole having a diameter of 0.8mm. The holes were drilled in a 1:1 staggered pattern of 22 rows x 79 columns and 22 rows x 78 columns in the spinnerette plate.

The spinnerette plate was fitted to a 65mm extruder which was connected to a staple fibre extrusion line. The extruder was charged with a narrow molecular

weight polypropylene polymer sold by the Shell Chemical Co under the grade no. PLZ987. The extruder and spinnerette were heated electrically, a temperature gradient of 196°C to 215°C was set on the extruder, and the spinnerette maintained a temperature of 210°C. The spinnerette and die head of the extruder were positioned so that the fibres were extruded horizontally.

On emerging from the spinnerette, the freshly formed fibres were chilled by directing a blast of cooling air so as to freeze into the fibres the differential stress and turbulence built into them by the shape of the holes in the spinnerette. The air temperature was maintained at 14°C and to give additional cooling, the fibres were passed around 1/3 of the circumference of a non-rotating segmented cooling roller which was situated 110mm from the spinnerette face. The roller was of 180mm diameter and was filled with circulating refrigerated water maintained at a temperature of 5°C. After passing around this refrigerated roller, the fibre tow passed through an air heated crystallisation oven and then to two sets of godet rollers of the staple fibre line.

The speed of the first godet rollers was adjusted to 25 metres per minute, and the second godet rollers to a speed of 75 metres per minute so that the fibre was subjected to a stretching ration of 3:1. Between the two godet sets a hot plate stretching device was situated so that the polypropylene fibres were in contact with this plate during the drawing process. The plate was maintained at a temperature of 100°C, and the speed of the extruder was so adjusted that the throughput of polymer gave fibres, after the stretching step, which were 15 denier per filament

(i.e. 9000 metres of a single fibre weighed 15 grammes).

From the last godet roller of the fast set of stretching rollers, the fibre tow was lubricated with spin finish oils and then passed to a drum cutter where the fibre tow was cut to staple of 100mm length.

As soon as the tension was removed from the fibre tow by cutting to separate short lengths of staple, the fibres immediately into a tight helical crimp. Examination of the helical crimp showed that it was a permanent effect and could not be removed by tensioning the fibre.

A batch of fibre which had been made in the manner described above was placed in a heat setting oven for a period of three minutes. The oven was maintained at a temperature of 130°C, and the heat set fibre was then removed and again examined and compared to the non heat set fibres. The heat set fibres had shrunk in length by 10% and the helical crimp frequency had increased and the fibre was even more resilient.

<u>Example 2</u>

Example 1 was repeated, but the drawing speed was increased to 95 metres per minute with a draw ratio of 3:1, and the extruder speed adjusted to produce drawn filaments with a denier of 12 denier. On allowing the fibre to relax free of tension, the fibres spontaneously formed into tight helical crimps. On heat setting, the fibre was even more resilient.

Example 3

Example 2 was repeated with the exception that the output of the extruder was reduced so that the final denier of the fibre was 6 denier per filament. On allowing the fibre to relax free of tension, the fibres spontaneously formed into tight helical crimps. On heat setting, the fibre was even more resilient.

Example 4

Example 1 was repeated with the exception that the spinnerette was replaced by one drilled with the same number and layout of holes except that the hole cross-section was circular rather than as shown in Figure 6. The holes were arranged in the normal manner as would be carried out by a person skilled in the art of extruding synthetic fibres. The circular cross-section would produce the minimum of turbulence in the polymer flow immediately prior to, or at the point of, formation of the filaments.

The fibre extrusion line and extruder were operated exactly in the manner of example 1 and 15 denier fibre was produced. When these fibres were cut into staple lengths of 100mm and all tensions released, they did not crimp into a helical form but remained generally straight with only a slight undulation. The fibres remained unchanged even after heat setting and were not highly resilient.

Example 5

Example 4 was repeated using the same spinnerette as in example 4 with round holes, but with the exception

that the fibres were deflected from a horizontal path by lowering the cooling contact roller so that the angle of the fibres was 45° from the horizontal. When these fibres were cut into 100mm staple lengths, they formed into a helical crimp.

Example 6

Example 1 was repeated with the exception that the spinnerette was replaced with one having the same number of holes laid out in exactly the same pattern and of the same cross-sectional shape as shown in Figure 6, but the holes were drilled at an angle of 45° to the horizontal as shown in Figure 1. Fibres with a denier of 15, 12, 10, 8, 6, 5, 4 were prepared using the extrusion conditions and godet speeds as previously described.

In each case, the fibres were prepared using this angle of drilling of 45° had a higher degree of helical crimp when compared to the same cross-sectional shape of fibre but where the holes in the spinnerette were drilled at 90°.

It will be appreciated by persons skilled in the art that the above embodiments and examples have been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims.

CLAIMS:

1. A method for producing a substantial helical or zig-zag crimp in a continuous filament, the method comprising the steps of generating a turbulence in a thermoplastic material intended to form the filament whilst the thermoplastics material is in its glass transition phase and maintaining stresses induced in the formed filament by said turbulence whilst the filament material passes into its crystallised phase.

2. A method according to claim 1, wherein the turbulence is concentrated towards one side of the cross-section of the filament.

3. A method according to claim 1 or 2, wherein the molten filaments are rapidly cooled to solidification.

4. A method according to any one of the preceding claims, further comprising the step of drawing the filaments through holes in a spinnerette plate wherein each hole makes an angle to an external face of the spinnerette plate.

5. A method according to claim 4, wherein each hole makes an angle of substantially 45 degrees to the face of the spinnerette plate.

6. A method according to any one of the preceding claims, wherein the turbulence in the molten plastics is generated by a change of the cross-sectional area of each hole through the spinnerette plate.

7. A method according to claim 6, wherein the change of cross-sectional area of each hole through the spinnerette plate is in the form of a step.

8. A method according to any one of the preceding claims, wherein each said filament has a non-circular cross-sectional area.

9. A method according to claim 8, wherein each said filament has a cross-sectional shape which is generally equivalent to a full circular cross-section with substantially one quarter of the circle removed.

10. A method according to claim 8 or 9, wherein the non-circular cross-sectional area of each filament is induced by the cross-section of a hole in a spinnerette.

11. A method for producing a substantial helical or zig-zag crimp in a continuous filament, the method substantially as hereinbefore described with reference to the accompanying drawings.

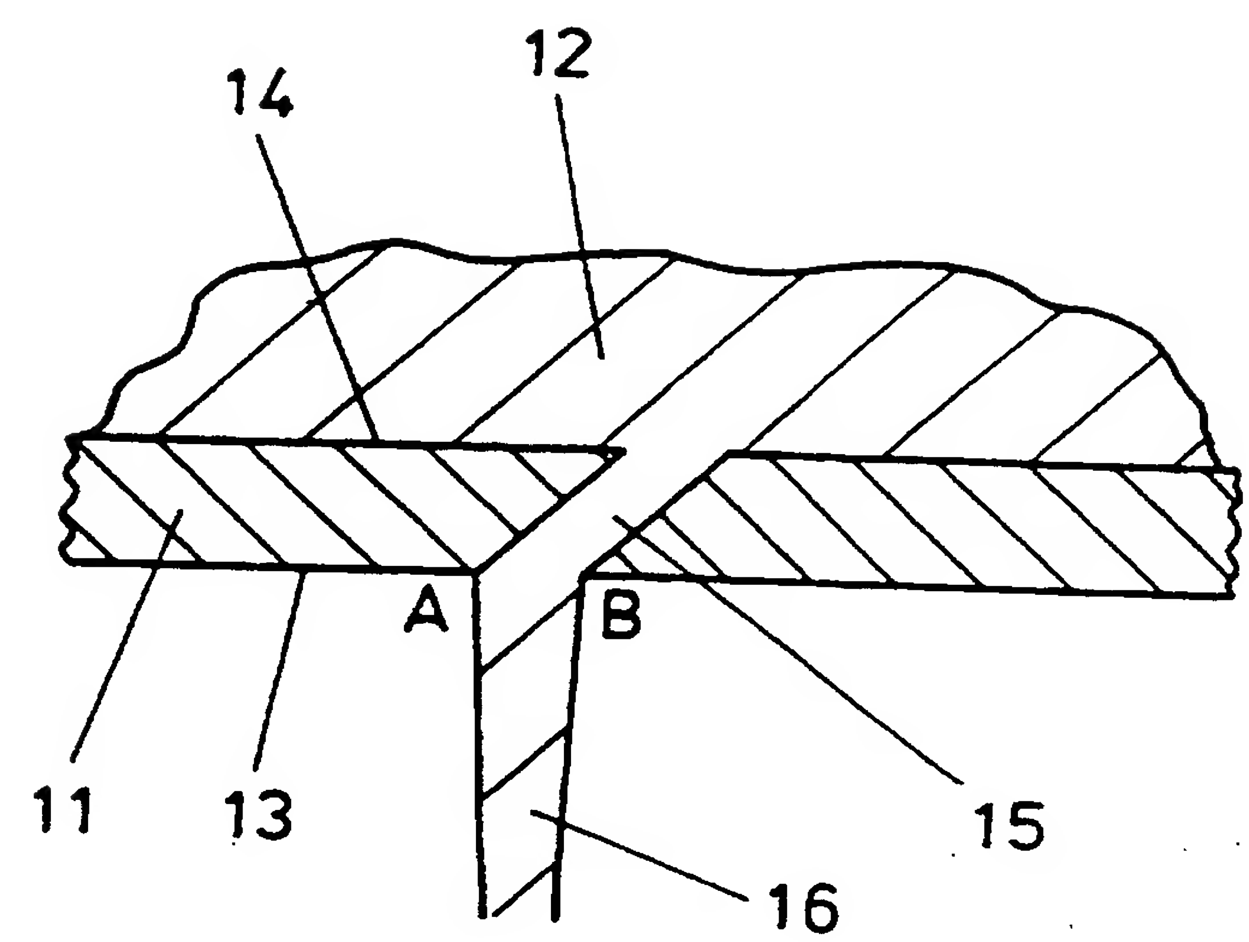

FIG. 1

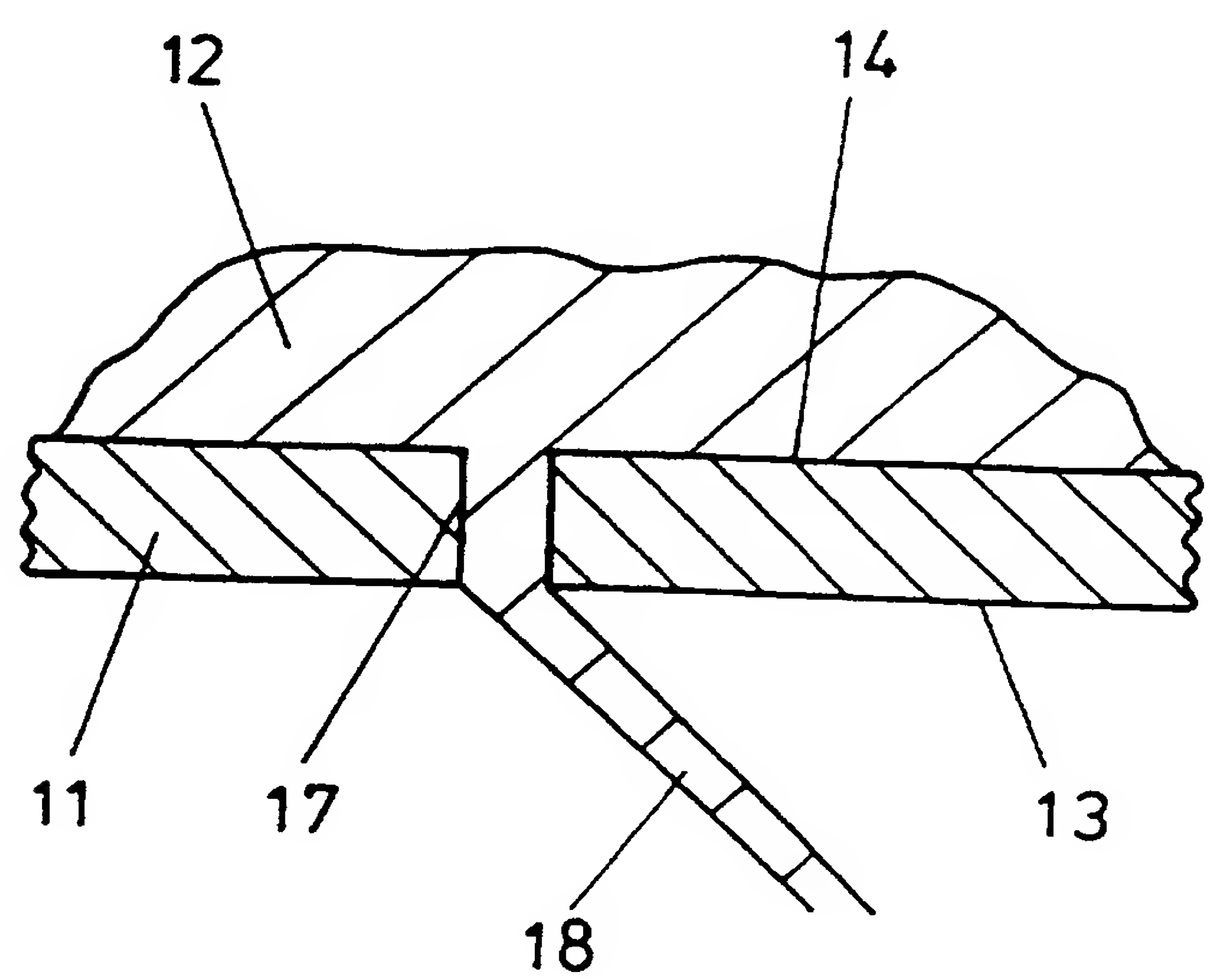

FIG. 2

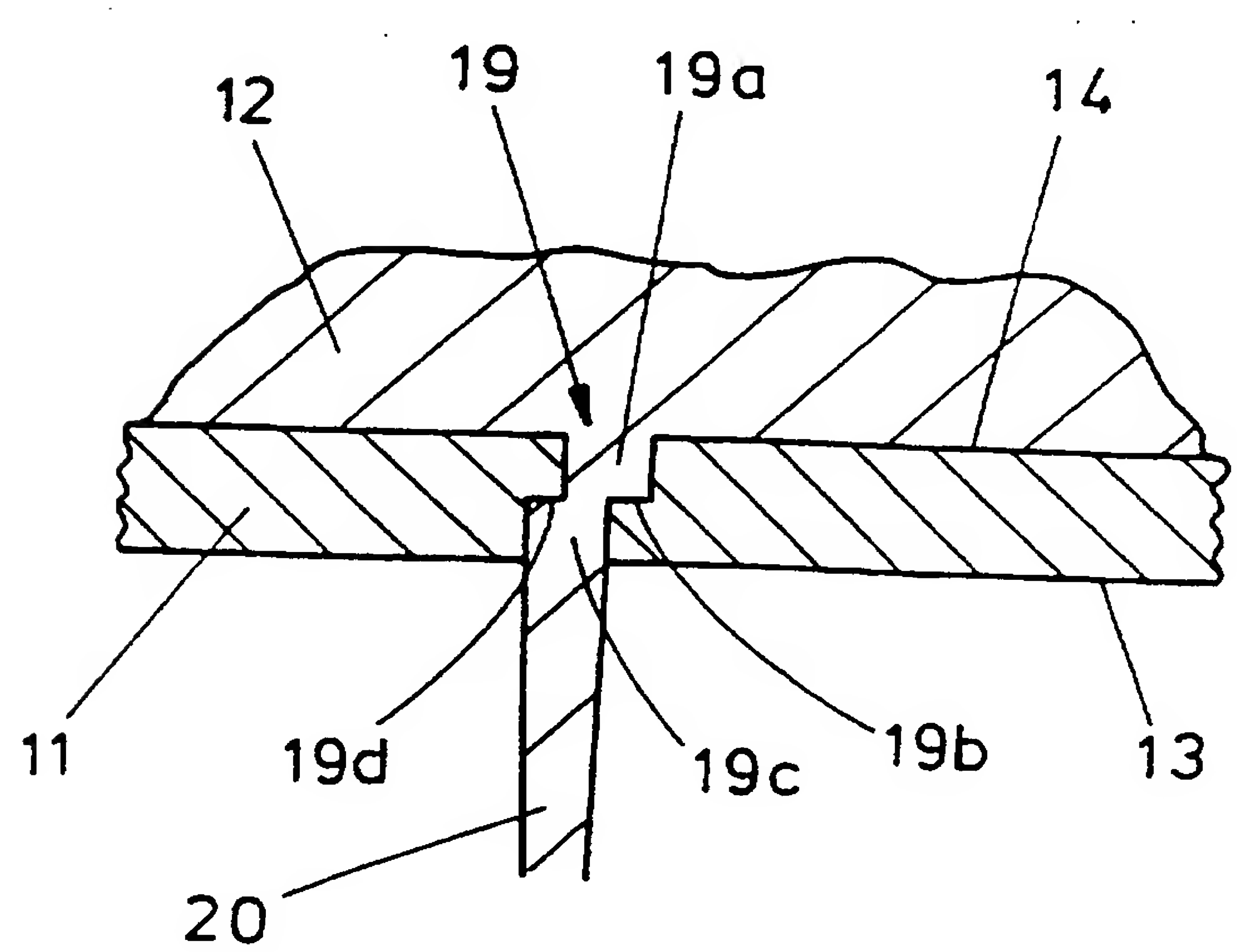

FIG. 3

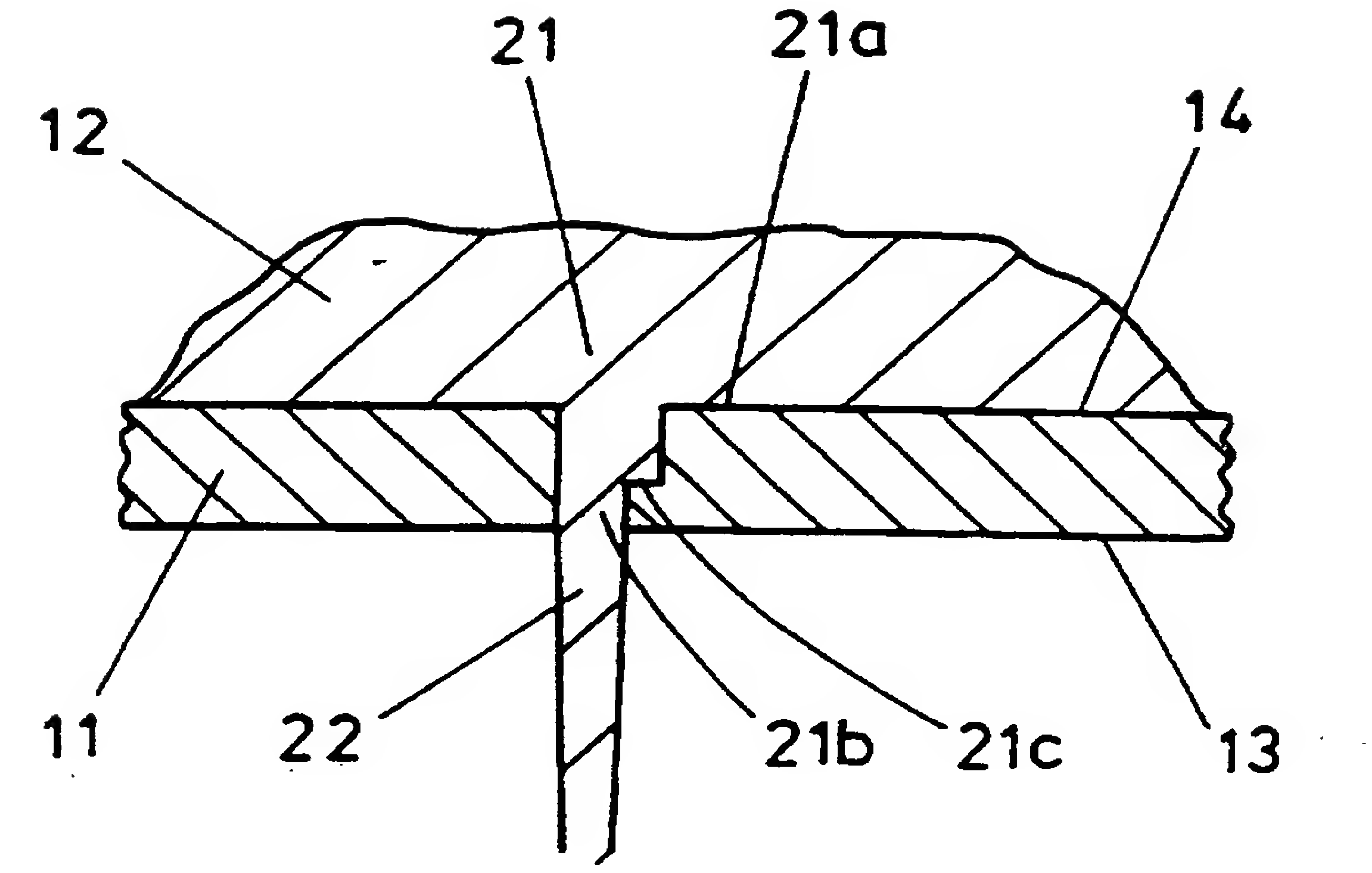

FIG. 4

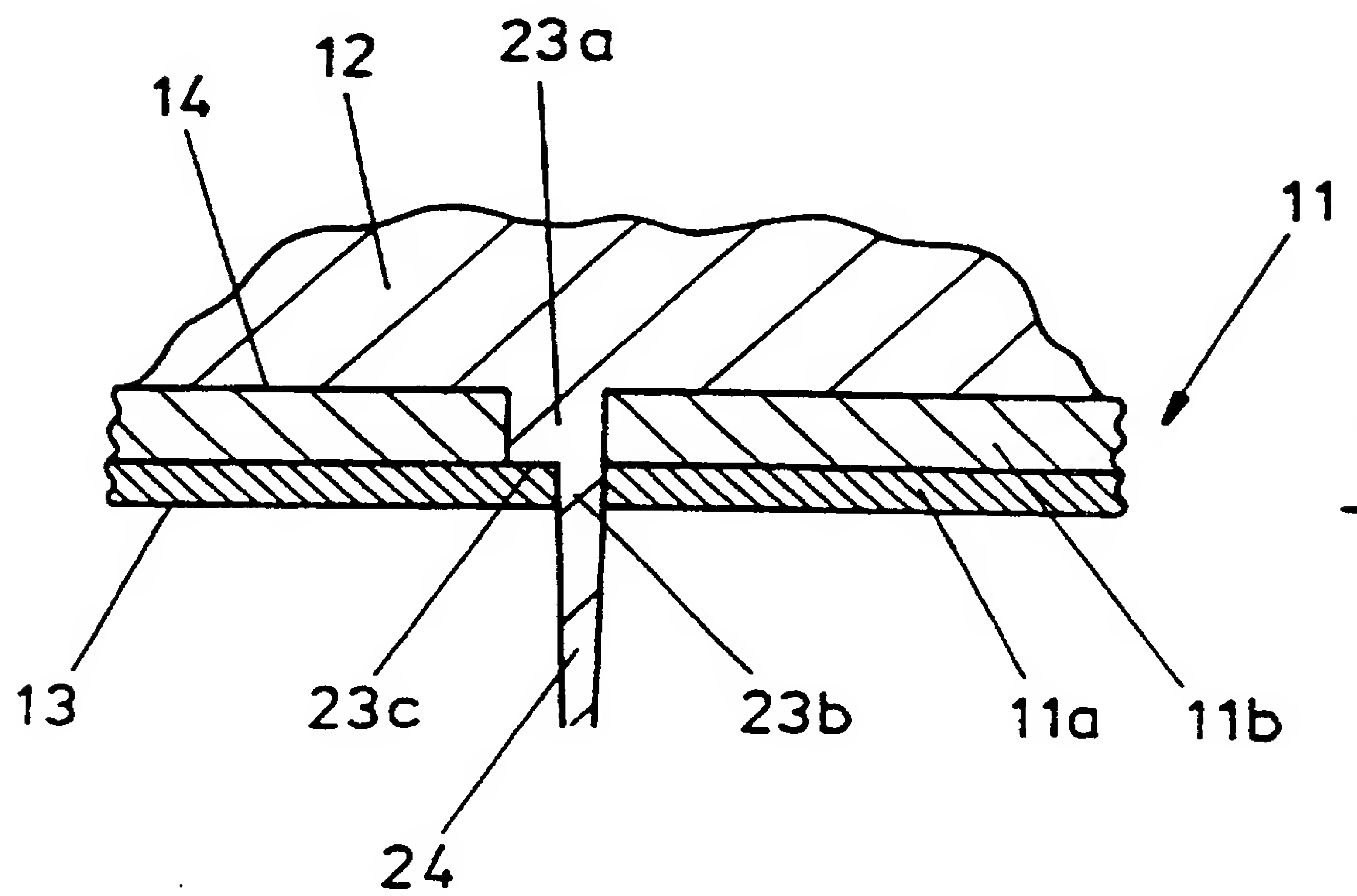

FIG. 5

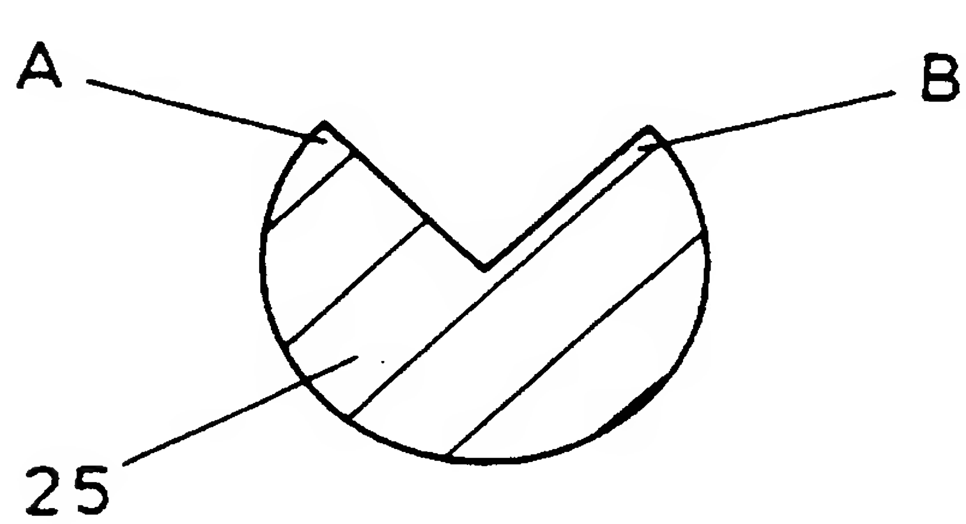

FIG. 6

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 96/02512

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 D02J1/08 D02G1/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 D02J D02G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB,A,1 126 552 (FIBER INDUSTRIES, INC.) 5 September 1968 see page 1, line 11 - page 2, line 39; example 1 ---	1-3
A	DATABASE WPI Section Ch, Derwent Publications Ltd., London, GB; Class A32, AN 72-45577T XP002024841 & JP,B,47 024 963 (TORAY INDS INC) see abstract ---	1
A	DE,B,12 19 165 (CELANESE CORPORATION OF AMERICA) 14 October 1959 see column 4, line 1 - column 5, line 5 --- -/--	6,8

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 February 1997	10.03.97

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,95 14799 (WELLMAN INC) 1 June 1995 see page 3, line 21 - page 5, line 31 -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 96/02512

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		CH-A-	453565	
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